AIRBORNE SEPARATION VIDEO SYSTEM (ASVS): "HIGH SPEED DIGITAL IMAGING"

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Abstract

Currently, flight-worthy, high-speed instrumentation film cameras are carried externally on aircraft to document the separation characteristics of stores released from aircraft. The compatibility engineer conducts qualitative analysis by reviewing the film post-flight. If a more precise analysis of the store's trajectory is necessary, further processing of the data is required for a quantitative analysis. The data provided by film works well for analysis, however, there are shortfalls associated with development time and cost of operating in blind conditions. There is no way of previewing the camera's settings and image quality in a real-time environment prior to store separation. The film must be developed before viewing, delaying turnaround time. Film processing and purchasing costs are expensive, film digitalization is costly and slow, and the processing of film is an environmental concern.

A digital imaging system referred to as the Airborne Separation Video System (ASVS) solves these issues. This paper will review the ASVS, the advantages of this system, and current program status.

Introduction

The Airborne Separation Video System (ASVS) also referred to as the Advanced Digital Imaging System (ADIS), is the first high-speed (1000 pictures per second) digital imaging system capable of operating in a military flight test environment. It is a proficient replacement of high-speed 16-mm and 35-mm film cameras for both flight and ground test and evaluation. The ASVS provides the tri-service communities with a cost efficient alternative to film. Replacement of film cameras eliminates several costs associated with the purchase, development, and disposal of film. It reduces or eliminates

environmental concerns and provides the ability to telemeter the data in real-time for analysis. The telemetered data from up to sixteen cameras provides the ability to preview a store/weapon prior to release and ensure that mission conditions and camera functions are acceptable. If conditions are not acceptable, camera settings may be changed or the mission may be aborted, thus, minimizing the number of weapons required to complete a program. The station engineers can perform a qualitative analysis in real-time and near real-time using the telemetered data during the event. The results of the mission are known prior to the program manager's decision for the next test.

The high-speed 16-mm film equivalent digital imaging camera, NTTC-V, has been installed on US Navy platforms (F/A-18C and F/A-18E), US Air Force (F-16) platforms, and US Army helicopters over the past year. It has proven its ability to streamline testing methods and shorten flight test schedules. During FY00 the high-speed 35-mm film equivalent digital camera, LTTC, will be fully developed and available for use on both airborne and ground-based configurations. This will continue to bolster the justification for the elimination of motion picture film at the majority of test and evaluation facilities.

CCD Technology

Charge Coupled Devices (CCD) have dominated the industry for the last 20 years. CCDs are sensitive integrated circuits capable of transporting individual photoelectrically generated charge packets into highly sensitive charge amplifiers with little degradation. CCDs have the ability to produce very high quality images, at high frames rate. However, there are a few drawbacks to CCDs. Due to the specialized fabrication process there is higher cost associated with CCDs. Additionally, the support circuitry is more complicated and there is limited ability to integrate support circuitry on the chip. Finally, blooming and/or smear is common under intense lighting conditions but can be minimized with the proper sensor design. However, CCDs have a number of advantages, which include the ability to produce very high quality images, the availability of electronic shuttering with simultaneous exposure of all pixels and the ability to operate at high frame rates.

CMOS Technology

Complementary mental-oxide semiconductor (CMOS) image sensors are fabricated like most computer chips and can be divided into active and passive pixel designs based on the circuitry. Passive pixel sensors are not suitable for motion analysis due to the image quality. CMOS have had limitations when compared to the CCD sensors, however these weaknesses are being addressed in ongoing research and development efforts by various manufactures. These limitations include a Higher Fixed Pattern Noise, which results in a "grainy" image, a possible solution is incorporating Correlated Double Sampling on the sensors. CMOS also has a limited ability to perform the electronic shuttering required to obtain exposure times shorter than the time between images and needed for motion analysis. CMOS image sensors also have a number of advantages over CCD sensors including lower cost due to the near-standard fabrication process and to the ability to integrate support circuitry on the chip. CMOS also incorporates a simpler support circuitry and has very little blooming and smear under intense lighting conditions.

The ASVS was required to function in lighting conditions that ranged from dusk to full sunlight. In addition to this large variation (sensitivity), the change from one moment to the next can be quite dramatic. To meet this

requirement a frame to frame electronic shutter was designed to automatically control the exposure time. Consequently, when the program began, CCD sensors were the only available technology that could meet ASV requirements. However, advances in recent months have produced a 1.3 M pixel, 1280 x 1024 electronically shuttered design. This new development will enable ASV to take advantage of CMOS superiority, including the ability to achieve a real-time output and variable resolution. Additionally, using CMOS sensors will open the door for digital cameras with higher frame rates and greater resolution then what is available at the present time.

ASVS

NTTC Digital Cameras

The Near Term Test Capability Prototype (NTTC-P) was the first generation of the NTTC digital camera family. The NTTC-P is a 16-mm film replacement with 512 X 512 pixel resolution. It can operate at 30, 200 or 400 pictures per second (pps). The digital images are time-tagged at the time of exposure to enable data merge with asynchronous sources for analysis. The images are stored in the camera's volatile memory that can be downloaded to recorder and/or telemetered to the ground. With a 33% reduction in size, the NTTC-V is a miniaturized version of the NTTC-P, but with an improved CCD that is capable of a 1000 pps frame rate and upgradable to color.

In many test configurations the location of the sensor can be a very small area. To meet this requirement a remote sensor configuration of the NTTC–V camera was developed. The NTTC-RS has the head, or sensor portion, of the camera as a separate entity that may be located up to thirty (30) feet away from body, or electronic portion of the camera. This is ideal for installation on low radar cross section aircraft platforms.

The latest generation in the NTTC digital camera family is the Long Term Test Capability (LTTC) which is a 1024 x 1024 pixel resolution camera (35-mm film replacement) which will operate at 500 pps. The LTTC is under final design and will be the same size as the NTTC-V with production anticipated in late 2000.

As ASVS developed, a survey was conducted among the Range Commander's Council - Optical Systems Group (RCC-OSG) members to better identify ground based and follow on user requirements. Responses were prioritized and incorporated in the A-Specification, which has been updated as needed to meet changing requirements. Based on the A-Specification a system was designed, built and tested that resolved many unique issues associated with an advanced digital system.

Real-Time Preview Mode

The expense of conducting test and evaluation on aircraft are often compounded by poor lighting conditions, incorrect camera settings, camera system malfunctions, fogged lenses, etc., which produce insufficient data and necessitate re-testing of a data point. The ASVS has a preview mode that allows the user to view the transmitted images in real-time and see what the camera is actually seeing. The images are transmitted at 30 pps to the receiving station. Built-In Tests (BITs) are run in the background and all errors are displayed to the user. The preview mode ensures that the test conditions have been met and the camera is functioning properly prior to performing the test.

Central Control

As today's avionics/weapon systems become more advanced requirements arise for large number of cameras to be installed to monitor tests at various distances from the events. Currently, cameras can be mounted within a pod, in the free air stream on a wing tip, in enclosures or pylons, or on ground based pedestals. In each instance there could be up to thirty cameras involved. To ensure accuracy and synchronization of data and to meet limited space requirements a single central control unit was needed. The ASVS was designed with the capability to control multiple streams of daisy chained cameras from one central control system. The controller provides the single interface to program, initiate, terminate, and record camera functions. Upon reception of a trigger signal each camera may record images for preprogrammed times before, during and/or after signal reception.

Cockpit Control Unit (CCU)

Since the ASVS has the capability to preview the mission and allow the test engineer to identify anomalies prior to weapon separation, the ability to modify system settings in real-time became a requirement. A user interface was designed to allow the user to optimize all system settings prior to continuing with the test.

Controller/Recorder Unit (CRU)

Converting digital data to analog images results in degradation in resolution and causes delay in data analysis. Therefore, the ASVS requirement is to store the images digitally at all times for post flight qualitative and quantitative analysis.

To store the images in digital format requires an increase in the amount of memory in a small-ruggedized package. To resolve this issue the images are stored in volatile memory within the camera and then downloaded to non-volatile memory in the recorder unit or to a data communication system for transmission (with or without encryption). The recorder memory was designed as a modular unit that can be replaced as technology advancements to allow for increased data byte storage.

Data Transmission System (DTS)

The DTS accepts digital images from the CRU and uses a video compression system which adheres to IRIG Standard 210 to compress, encrypt and transmit these images to the ground over a non specific frequency with either 5 or 10 MHz bandwidth where they are decoded and displayed.

Ground Interface Unit (GIU)

An essential element of the ASVS is the GIU, which interfaces with the CRU to configure the ASVS on the ground for flight and to download the images stored in the CRU postflight for viewing and analysis.

Qualitative Data Reduction System (QDRS)

The QDRS is a Gateway personal computer. It will contain a 500 MHz Pentium III processor, 18.0 Gbyte removable hard drive, 256 Mbytes of RAM, a DRS-proprietary Color Video Processor (CVP) card, a read/write CD drive, an Exabyte Mammoth tape drive, and a 100 GB RAID (redundant array of independent disks). The CVP card is used to decompress and reconstruct color ASV images. The QDRS is used to view the ASVS digital images to make a qualitative assessment of the store's separation characteristics. Special QDRS software will be developed to meet the functional capabilities determined by the government.

Multi-System Controller (MSC)

During the development of ASVS it became quickly apparent that there was a requirement for a standalone system for both airborne and ground based units. The MSC combines the functions of the CRU and the CCU, can be remotely controlled and can be co-located with the camera. In the airborne standalone configuration, the ASVS can be used even when the aircraft has not been modified with cabling by utilizing an instrumentation pod connected to the aircraft for power and trigger/event signals only. In the ground configuration the ASVS can be installed on tracking pedestals. In both cases, the system operates autonomously as preprogrammed by the user. As with the other configurations, the digital images are available in near or real-time for analysis.

Encryption

It is a requirement during the majority of tests on military facilities to encrypt weapons system data. All ASVS image data can be encrypted for transmission then decrypted upon reception with no degradation in resolution. This permits telemetry in free air space without fear of compromising the test mission (the ASVS also will work without encryption).

Environmental

Each component of the ASVS was required to meet the requirements of the operational and endurance environments of all military aircraft equipment with no degradation of system performance. This included: altitude/temperature, Salt/Fog, Humidity, Shock, Temperature Shock, Dust, Acceleration, Vibration, AC and DC Power input and Electromagnetic Interference (EMI). This ruggedization was accomplished using Commercial-Off-The-Shelf (COTS) equipment as much as possible. Including cost effective RAM modules, data cables, power supplies and design electronics.

System Testing

In performing, ASVS system acceptance testing, both static and dynamic component and system level tests were conducted. All configurations are fully ruggedized. Figure 1 illustrates the ASVS configuration.

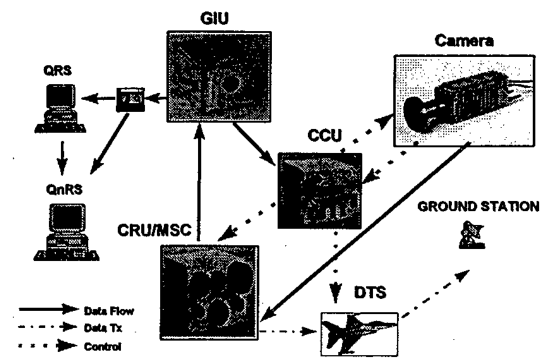

Figure 1 ASVS Configuration

Laboratory Testing

Laboratory tests included performing environmental testing to ensure compliance with all environmental and EMI requirements and First Article Testing (FAT) tests were performed to prove that ASVS met all functional and performance requirements as delineated in the A-Specification. One of the FAT compliance tests was to ensure that cameras met system resolution requirements. Comparing the Contrast Transfer Function (CTF) and Modulation Transfer Function (MTF) to that of 16-mm film performed this test. Results show that the ASVS images provided consistently better performance than that of digitized 16-mm film and that there is superiority in preserving high spatial frequency (fine) detail in the ASVS images.

Ground Test

Upon successful completion of the environmental testing and FAT, the ASVS was delivered to the Government for testing. Ground tests included static and dynamic tests. A series of eight individual bomb drop tests were performed. The bomb was surveyed using traditional theodolite survey equipment at the beginning and terminal locations to ensure quality control information. Truth data was provided by a control camera, which remained at a fixed distance from the target. A set of 16-mm film and ASVS cameras were positioned eight (8) feet from the bomb drop area and moved further away with each test, eventually reaching a maximum of thirty-five (35) feet from the target area. It was anticipated that the digital imaging accuracy would equal that of the film system at closer range and then degrade as the distance increased. Results of the quantitative data reduction system (QDRS) showed the NTTC digital data compared favorably with the 16-mm film data and in most cases exceeded the 16-mm film's performance. The bomb drop tests confirmed the ASVS as an acceptable replacement to current 16-mm cameras.

Flight Test

Rotary Wing

A flight test on a rotary wing platform was successfully performed to confirm aircraft compatibility and environmental and EMI performance in an operational environment. More rotary wing tests are scheduled to confirm the capability to function with the higher vibration requirements of these platforms in real world scenarios.

Fixed Wing

A Navy test aircraft had the ASVS wiring installed and completed first flight on 26 March 1998. The purpose of the flight was to release two (2) bombs, record the drop with three ASVS digital cameras and three film cameras for post flight comparison purposes. All of the ASVS NTTC cameras and the film cameras mounted on the aircraft captured detailed images of the ordnance drops. The ASVS camera images were then compared to the film camera images. Accuracy results were consistent with the ground bomb test results and continued to show that the ASVS is an acceptable replacement to the film.

The second flight consisted of only one NTTC camera (on the aircraft tail) and three film cameras (left wing, right wing, and tail). During flight, two film cameras failed while the NTTC camera successfully captured the digital images for post flight qualitative and quantitative analysis.

Additional flight tests were successfully conducted on both Navy and Air Force aircraft recording various store separations.

Mission Support

After completing the initial testing phase, the ASVS has been used to provide mission support for aircraft and ordnance acceptance testing. The ASVS was used to evaluate arrestment certification testing of the F/A-18 aircraft during aircraft carrier suitability testing. Additionally, the system was used for ground testing of bomb drops for a test that consisted of 600 test drops. The ASVS saved countless hours of data reduction and greatly reduced/eliminated test costs normally associated with tests conducted using film cameras.

Future Plans

The program will continue with the development of the MSC and the LTTC camera with its 1024 x 1024 pixel resolution to be comparable to 35-mm film cameras. In addition, plans exist for the Ultra High Speed/Resolution Camera, 4096 x 4096 pixel resolution (70-mm replacement) operating at 400 pps, which would also allow for 512 x 512 pixel resolution at up to 20,000 fps .

In addition to camera improvements a digital telemetry system is being developed. This capability will allow the recorded images to be sent to the ground and feed to the analysis tool prior to the aircraft landing. This will help to speed up the analysis process.

Conclusion

Advancements in CCD technology, digital memory capacity both DRAM and hard drive, and transmission/processing speeds are making digital imaging an acceptable, cost-effective, reliable, and workable solution to experimental T&E requirements and environmental safety requirements.

Biography

Mr. Paust obtained his Bachelor of Engineering degree in Electrical Engineering from Virginia Polytechnic and State University.

Mr. Paust is the Program Manager of the Advanced Separation Video System (ASVS) currently being developed and tested at the Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland. Past experience includes software and hardware development for **Global Positioning System** (GPS) systems, hardware development for Electronic Warfare (EW) systems as well as GPS surveying.

Mr. Paust is an active member of the International Test and Evaluation Association (ITEA).

Mr. Pender obtained his Bachelor of Engineering degree in Electronics & Computer Engineering from George Mason University.

Mr. Pender is a Staff Specialist for the Office of the Secretary of Defense Ranges and Resources. Mr. Pender was the Program Manager of the Advanced Separation Video System (ASVS) currently being developed and tested at the Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland. Past experience includes Optics development, Global Positioning System (GPS) Surveying, Laser Safety and Development as well as teaching Digital Communications Theory in his spare time at the local community college.

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